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OF THE

CHEMICAL ANALYSIS OF POTABLE WATERS.

BY

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[A Paper read before the Albany Institute, April 7, 1885.]

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## THE SANITARY VALUE OF THE CHEMICAL ANALYSIS OF POTABLE WATERS.

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For the past six months or more the subject of our city water supply has received an unusual amount of attention from the citizens of Albany. Very naturally questions concerning the various methods of water analysis and their value have come under discussion, and it is possible, that a brief description of those processes which are employed by chemists to-day and a discussion of their respective merits may be of interest at this time. It may be profitable also to inquire what are the questions which a chemical analysis can positively answer and incidentally to consider the probabilities of disease transmission by water used for drinking and the effect of natural oxidation by aeration in purifying those which are polluted by sewage matter.

The general appearance and physical properties of a water will naturally first attract attention when its quality is questioned. An ideally pure water will be clear and colorless, odorless and tasteless, but these qualities, however desirable in themselves, do not necessarily indicate freedom from pollution. Waters which have penetrated through the soil are generally bright and clear from the filtration they have undergone, and may have neither odor nor taste and yet be very dirty waters chemically, while surface waters may show a decided color and even turbidity, may have an earthy, vegetable or peaty odor and taste and yet be quite free from harmful constituents. *Pure* water does not exist in nature, all dissolved or suspended substances being impurities in water as such, though by no means necessarily harmful. The sensible properties of a water, therefore, unless it be so foul that there is no mistaking its pollution, afford little information as to its quality. Water may percolate through the soil for a mile under a mountain and be as clear as crystal and yet carry typhoid fever from a hamlet on one side to dwellers on the other, as in the celebrated and well authenticated case at Lausen, Switzerland.

The suspended matter contained in potable waters, and naturally most abundant in surface waters, usually consists chiefly of clayey matter, easily removed by filtration on a large or small scale or by mere subsidence. In some cases, however, as in the James river water which supplies Richmond, the suspended matter is so finely divided

that its removal is well nigh impossible, but such matter may generally be disregarded as unimportant from a hygienic point of view. The dissolved constituents consist both of gaseous and solid substances. The former may be the atmospheric gases only and aside from the indications which the quantities of nitrogen and oxygen and the ratio between them are thought by some to afford as to the amounts of organic matter which are undergoing oxidation their quantity is of little importance. Sulphuretted hydrogen and other noxious gases may indeed be present as the result of putrefactive changes or peculiar conditions, and the recognition of such constituents may become a matter of importance, not because they are in themselves capable of producing disease in the quantities which may be present in water, but because their existence throws light upon the chemical changes which are taking place.

The dissolved solid constituents of potable waters are both inorganic and organic, the latter either of animal or vegetable origin. Up to twenty years ago the ordinary method of quantitative determination was to evaporate a definite quantity of the water to dryness in a platinum dish, weigh the residue, calculate the percentage of total solids, and then determine the organic or volatile matter by the loss resulting from the ignition of the total solid residue, due correction being made for the loss of carbonic acid. A complete analysis was then usually made of the mineral constituents, but as the precise amounts of these are of little importance and as the method described for determining the organic matter afforded no clue to its nature and was too inexact to be of value even in ascertaining the amount with accuracy, it may be readily seen that the results thus obtained were of little or no sanitary value. In speaking of the exact determination of the mineral constituents as unimportant reference was had to the lime, magnesia, iron and other salts usually occurring in all natural waters save rain water, and not to the chlorine, phosphoric acid, nitrates and nitrites which are important but which formerly received less attention than at present. For manufacturing purposes of course a soft water is generally to be preferred. Hard waters, however, act upon lead less than soft ones, while on the other hand they occasion a waste of soap and are not desirable for culinary purposes, but these are incidental questions, and it cannot be said to be proven that the amount of mineral matter in potable water exercises much influence upon its healthfulness. In most cases a mere determination of the hardness is quite sufficient, a water not too hard being generally preferred, though the total solids are likewise determined when a complete analysis is made.

Let us now briefly consider those inorganic constituents which are generally regarded as important from a hygienic standpoint.

1. *Chlorine.* — This occurs chiefly in combination with sodium. In waters not naturally brackish the determination of its amount is regarded as decidedly important. Chlorides occur in all human excreta and slop waters, and, therefore, in all sewage, and their presence in considerable quantity is a sign of probable contamination. The estimation is generally made volumetrically with a nitrate of silver solution. Over five parts in 100,000 were regarded by the Rivers Pollution Commission of Great Britain as in most cases due to sewage contamination.

2. *Phosphoric acid.* — "Much nonsense" says Wanklyn "has been talked about phosphates." This talk has had to do with the presence of phosphates in sewage and the evidence afforded by them of such contamination. The fact, however, is that in presence of carbonate of lime phosphates can only exist in exceedingly small traces in a clear water, but a qualitative test for their presence is usually made.

3. *Nitrites and nitrates.* — These compounds are believed to result mainly from the oxidation of nitrogenous organic matter, chiefly animal, and are considered by some chemists as indicating quite accurately the amount of such defilement. In themselves, of course, they are harmless, but if they aid us in determining the amount of pollution their quantity becomes a matter of importance. It is now pretty generally conceded that the conversion of nitrogenous organic matter into these forms takes place under the influence of micro-organisms and is a process of fermentation, the rapidity of which depends upon degree of dilution, temperature and other conditions. Recent experiments, as for instance, those of Warrington at the Rothamsted laboratory reported in *Nature*, for October 30, 1884, seem to prove quite conclusively that such is the case, and if so, the old view that nitrification is a mere oxidation must be abandoned and our ideas concerning the value of natural aeration, long considered by many chemists so important, must be greatly modified. Warrington asserts that nitrification will not take place in an acid solution. Some base must be present with which the nitric acid formed may combine, and when this is exhausted the oxidation ceases. If this is true then a study of the amount of certain mineral constituents present in a water which may furnish bases to the nitric acid produced, becomes indirectly important in determining the rapidity and completeness with which sewage matter may be oxidized, and a study of this subject, yet practically undeveloped, bids fair to yield valuable results.

At the same time it is to be borne in mind, as Wanklyn and others have pointed out, that certain mineral strata yield nitrates to water containing no organic matter, and that processes of vegetation in rivers

and lakes withdraw them from water. Also that nitrates once formed may be again reduced to ammonia compounds or even to free nitrogen. If so, then an undue importance has been attached to the determination of nitrogen in this form, by Frankland and others, who make use of the term "previous sewage contamination" to denote the amount of sewage which has been discharged into a water and undergone oxidation, estimating the same by determining the total combined inorganic nitrogen present, as ammonia, nitrates and nitrites, and after deducting the amount of nitrogen present in these forms in rain water, calculating how much "average London sewage" would be required to account for it. It will therefore be seen that much difference of opinion exists as to the degree of importance to be attached to the presence of these compounds in water, and that the questions involved are exceedingly intricate and as yet very far from being settled. Various methods are employed in their determination, none of which are perfectly satisfactory.

We may now dismiss from further consideration the inorganic constituents of potable waters, and proceed to describe those methods of analysis developed during late years, which have for their object the determination of the amount and so far as possible the nature of the organic constituents, so much more important than the inorganic, from a sanitary point of view. The following are the most important of these processes:

1. *Permanganate methods.*—In 1849 Forchammer proposed the use of permanganate of potassium for the determination of the oxidizable matter in water. This salt imparts, even in very small quantities, a decided pink color to water, and as it contains a large amount of oxygen which it readily gives up to reducing bodies, thereby losing its characteristic color, its use affords a ready method for the determination of the amount of many such substances in a state of solution. As applied to the determination of organic matter however, the results can have no absolute value, since different kinds of organic matter require for oxidation different amounts of oxygen, and moreover differ in the completeness with which they are oxidized and the length of time required. Much also depends upon the exact method in which the test is applied, and various inorganic compounds which may be present, reduce the permanganate and become a source of error. Nevertheless this test has a certain value, and it was at one time even thought that the amounts of putrescible matter might be estimated by the amount of permanganate decolorized during the first few minutes, since such matter probably first undergoes oxidation. Frankland held this view, as did Angus Smith, but the former has of late entertained a different opinion. W. A. Miller, Kubel, Tidy, Letheby, Schultze and others

have proposed particular methods for the application of this test, that most in use at the present time being Tidy's modification which consists in the addition of a definite amount of permanganate solution to a certain quantity of the water acidified with sulphuric acid. At the end of a certain length of time the amount of permanganate remaining is determined and the amount of oxygen consumed is calculated and reported as "oxygen absorbed." Very generally, two determinations are made on different samples of the water, the permanganate being allowed to act for fifteen minutes in one case and for three or four hours in the other.

Tidy and his adherents attach great importance to the results thus obtained. Frankland admits that they are not without value, and finds that they corresponded in 1418 out of 1686 cases quite closely with those obtained by his own very elaborate method presently to be described. Wanklyn condemns the method as misleading on account of want of delicacy and the fact that albumen is not readily attacked by the standard solution of permanganate, while, as Frankland long ago pointed out, such bodies as starch and cane sugar take up less than the one-hundredth part of the oxygen required for total oxidation. The majority of water analysts probably realize the imperfections of all permanganate methods, but consider their indications as not without a certain value. In this connection it may be remarked that Wanklyn has proposed and patented a method known as the "moist combustion process," in which an alkaline solution of permanganate is distilled with the water and the amount of permanganate consumed determined. It has not been received with much favor.

2. *Wanklyn and Chapman's albumenoid-ammonia process.* — The ammonia method so well known and largely employed at the present time was brought forward by Wanklyn, Chapman and Smith in 1867. The modified process now in general use is described in the fifth edition of Wanklyn and Chapman's *Water Analysis*. No method has ever found such general favor among analysts, a fact, perhaps in part owing to the comparative ease, with which the test is applied, the general nicety of the process and the seeming accuracy — certainly delicacy — of the method. Nevertheless it has been harshly criticised by many and especially by Frankland and his followers.

In this test a definite quantity of water is boiled in a retort, some carbonate of sodium having been added if necessary to render the water alkaline, and the ammonia which existed as such in the water or has resulted from the decomposition of urea and like substances, passes over with the escaping steam which is condensed and the amount determined with Nessler's solution and reported as "free ammonia." When this has all been given off an alkaline solution of permanganate of

potassium is added, and the distillation continued. Certain kinds of organic matter containing nitrogen are thus decomposed, giving off a part or all of their nitrogen as ammonia, and since albumen is one of these, the ammonia so obtained is called "albumenoid-ammonia," and reported as such.

This process was the first to come into general use which claimed to distinguish readily putrescible nitrogenous matter from those organic substances which are with greater difficulty converted into ammonia, and much importance was naturally attached to the results obtained in distinguishing pollution due to animal matter from that of vegetable origin, but as different amounts of ammonia are yielded by the same weights of different substances, and as the conversion of many such into ammonia is by no means complete, the results can have no absolute significance. On these and other grounds Frankland rejects this method utterly. Tidy, likewise, while admitting that the process might be used to discriminate between a water of excellent quality and one exceedingly bad, holds that when water of intermediate character is under examination, it "utterly and entirely fails." It is to be borne in mind, however, that both Frankland and Tidy are committed to methods of their own, which they advocate not without the exhibition of a partisan spirit, and their conclusions are, therefore, hardly entitled to the same weight as those of less prejudiced, though, perhaps, less distinguished, experts. The rank and file of water analysts have accepted this method as affording very valuable information, and in the elaborate *Preliminary Report on the Results of an investigation made by direction of the National Board of Health, as to the chemical methods in use for the determination of organic matter in potable water*, made by Professor Mallet of the University of Virginia, in 1881, and printed in the report of the National Board of Health for 1882, the author, while he points out the defects of the process, finds "that it is admittedly simple and easily carried out;" that "the value of the results depends more upon watching the progress and rate of the evolution of the ammonia, than upon determining the total amount;" and that "taking the results by this process as recorded, we find a great deal of similarity between the figures for albumenoid ammonia and those for organic nitrogen (by the combustion process), but with frequent discrepancies of varying extent such as prevent the one being taken as the accurate measure of the other."

3. *Frankland and Armstrong's combustion process.*—This is the third and last of the important processes now in use. It was brought forward by its originators in 1867, and first described in print in the *Journal of the Chemical Society* (London) for March, 1868, and is by far the most elaborate method of any in use. It was employed by the Rivers

Pollution Commission of Great Britain in the examination of a large number of waters. The process consists in the evaporation of a stated quantity of the water which has been freed from all the carbon and nitrogen which existed in it in an inorganic form, excepting in ammonia, by treatment with a saturated solution of sulphurous acid, by which the nitrates and nitrites are reduced with the expulsion of their nitrogen and the carbonates decomposed with liberation of their carbonic acid. Nitrogen in ammonia is fixed and has to be deducted in the final computation. The residue obtained is then submitted to organic analysis, resulting in the conversion of the carbon into carbonic acid and the liberation of the nitrogen as such. The mixture of gases is then subjected to volumetric gas-analysis and the results finally reported as parts of "organic carbon" and "organic nitrogen" in 100,000 of water. The relative proportion of nitrogen to carbon is supposed to throw light upon the nature of the organic matter originally present, since in animal substances the ratio is higher than in vegetable. Frankland finds that the ratio of nitrogen to carbon is for upland surface waters, on an average, 1 to 10; for water from cultivated land, 1 to 6; for shallow wells, 1 to 4; for sewage, 1 to 2. It has been found, however, that the effect of oxidation upon peaty matter is to diminish the proportion of carbon, while during the oxidation of animal matter it is the nitrogen which diminishes most rapidly. Therefore the proportions of nitrogen to carbon in vegetable and animal matter vary in opposite directions during oxidation, a fact which greatly adds to the difficulty of deciding as to the nature of the organic matter present.

This process is, in theory, the most scientific and accurate of any ever proposed, but it is exceedingly difficult, requiring costly and elaborate apparatus and especial skill on the part of the operator. Mallet says, "It is better adapted to regular use in the analysis of many samples of water in a large public laboratory than to occasional use by a private individual in now and then examining a sample of water." For these reasons, chiefly, it has not come into general use and in this country it has been employed by but very few chemists. Objections on the score of difficulty, however, should not be allowed to weigh against the process itself if it is of value, but on this point much difference of opinion exists. As might be supposed, Wanklyn and Tidy condemn it, and while most chemists admit that the principle is a good one, it is pretty generally believed that its indications are by no means as reliable as they are claimed to be by the originators of the process. Mallet, after summing up its errors and the objections to it, says: "The combustion process, in its present form, cannot be considered as 'determining' the carbon and nitrogen of the organic mat-

ter of a water in a sense to justify the claim of ‘absolute’ value for its results, which have been denied to those of all other methods. It is but a method of approximation involving sundry errors, and in part a balance of errors.”

These then are the principal methods and the best at present known for the determination of organic matter in potable water.\* It will be seen that no one of them enables us to recognize the real morbific material which water may contain or is able to distinguish with certainty between disease-producing constituents and the less harmful or innocent matter of vegetable origin, or that which has resulted from the conversion of harmful into harmless substances. The English “Society of Public Analysts” have adopted a scheme of analysis which includes both the permanganate and albumenoid-ammonia processes, and this method has been largely followed in this country and adopted by our State Board of Health. I have employed it in quite a large number of cases, and it has frequently happened that waters which had in all probability caused disease, could not be condemned on the evidence furnished by the analysis alone. Mallet would use “all three of the principal processes,” since “each gives a certain amount of information which the others do not afford,” and adds that “under circumstances admitting only of the use of simpler means of investigation, the albumenoid-ammonia and permanganate processes might be employed together, but in no case should only one of these methods be resorted to, such a course entailing practically the neglect of carbon on the one hand or nitrogen on the other.” This opinion is based upon the results of an extended research, and to admit that the determination of carbon and nitrogen — perfectly harmless elements in themselves — affords us our best indications in judging of the purity or impurity of a water is to acknowledge that our best analytical methods are far from satisfactory.

What, then, are the questions which a chemical analysis can answer concerning a water viewed from a hygienic standpoint? It may be answered, first, that all attempts to establish definite standards, so that the points for and against a water can be counted up and a balance struck, have signally failed. For there is no unanimity of opinion as to what degree of importance should be attached to the results obtained, and if there was, such a numerical expression of their relative importance must of necessity be arbitrary and misleading. A committee of the German Public Health Association reported to

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\* The scope and limits of this paper do not admit of a consideration of certain recently proposed analytical processes like the “actinic method” in which silver salts in solution are reduced by organic matter when exposed to sunlight, nor of indirect methods of analysis like the determination of the gaseous constituents to which reference has been made.

this effect at the Dusseldorf meeting in 1883, and the opinion of this committee accords with that of most sanitarians who have investigated the subject.

Secondly, it may be said that with the various means at present at our command, waters which are very pure, chemically, of medium purity and foul, may be distinguished, but whether these waters are therefore safe to use, doubtful or harmful, must be a matter of opinion, and is not to be decided by the analytical results. You may take a few spoonfuls of the dejection of a typhoid-fever patient and add them to a barrel of distilled water, and a chemical analysis will tell us that the water is pure, and you may add a pound of healthy faecal matter to an other barrel of distilled water, and an analysis will show that it is defiled, yet the first water may, if drunk, give rise to typhoid fever, and the second to no harmful results at all. The analysis of water is like that of air. It can show us the relative amounts of the main and gross constituents, but the organized and living material which may be present, and if so is probably most instrumental in producing disease, can be neither recognized as such nor measured. In the appendix to the report of the Medical Officer of the Local Government Board of Great Britain for 1881, is a report by Dr. Cory on the chemical examination of certain samples of water purposely polluted with excrements from enteric-fever patients and other matters. Dr. Buchanan sums up the result of the inquiry by saying: "While we must ever be on the watch for the indications that chemistry affords of contaminating matters gaining access to our waters, we must (at any rate until other methods of recognition are discovered) go beyond the laboratory for evidence of any drinking water being free from dangerous organic pollution. Unless the chemist is well acquainted with the origin and liabilities of the water he is examining, he is not justified in speaking of a water as 'safe' or 'wholesome' if it contains any trace of organic matter whatever; hardly, indeed, even if it contains absolutely none of such matter appreciable by his very delicate methods. The chemist can, indeed, tell us of impurity and hazard, but not of purity and safety. For information about these we must go, with what the chemist has been able to teach us, in search of the conditions surrounding water sources and affecting water services."

We are not, therefore, to infer that water analysis is useless because in the present state of our knowledge there are many questions which it cannot satisfactorily answer, for an analysis of a water may reveal to us the presence of compounds which have doubtless resulted from the decomposition of animal matter, as, for instance, in showing us that a well is contaminated by leakage from a cess-pool or privy, or that a

reservoir, pond or river is defiled by sewage matter. Now in the first case the pollution of the well may be harmless, but in the event of specific polluting material entering at any time, as it is quite likely to do at some time, such a well may become a center for spreading disease, and if so its water should not be used at all, and in the other case, if a larger body of water is markedly polluted by sewage, while the certainty of its proving unwholesome or producing specific diseases may not be provable, we shall err on the safe side if we refuse to use such water, the chemical evidence being considered, at least, until we can cut off the access of contaminating matter.

And lastly an analysis may assure us that a given water is of such a degree of purity that the probabilities are that it carries with it no harmful matter, but this kind of evidence is always to be received with caution unless the results of the examination are borne out by other evidence which proves that pollution is not probable. Thus while a chemical analysis alone cannot tell us that a water is absolutely safe or necessarily harmful, it *can* tell us that a water contains those constituents which may reasonably be believed to accompany harmful matter, and if the question be as to the employment of a given water for a city supply, an exhaustive series of analyses made at different points, stages, times and seasons may reveal to us the degree of pollution, points at which the polluting matter enters, rapidity of its destruction by natural processes, and the conditions of the water under varying circumstances, and also indicate to us the methods to be employed for improving its quality and obtaining it at its best estate. Such series of analyses have been made during late years in our own country by various chemists, and with very satisfactory results. But a single analysis, or a few analyses, may give us little information or be entirely misleading.

Previous reference has been made to the investigations of Professor Mallet, and as no more thorough work has probably ever been done in this direction, at home or abroad, and as the conclusions arrived at as the result of an exhaustive study of a multitude of facts confirm the opinions just expressed, some of these conclusions from his report are quoted:

"1. It is not possible to decide absolutely upon the wholesomeness or unwholesomeness of a drinking water by the mere use of any of the processes examined for the estimation of organic matter or its constituents."

"2. I would even go further and say that in judging the sanitary character of a water, not only must such processes be used in conjunction with the investigation of other evidence of a more general sort as to the source and history of the water, but should even be

deemed of secondary importance in weighing the reasons for accepting or rejecting a water not manifestly unfit for drinking on other grounds."

"3. There are no sound grounds on which to establish such general 'standards of purity' as have been proposed, looking to exact amounts of organic carbon or nitrogen, 'albumenoid-ammonia,' oxygen of permanganate consumed, etc., as permissible or not."

"4. Two entirely legitimate directions seem to be open for the useful examination by chemical means of the organic constituents of drinking water, namely: first, the detection of *very gross* pollution, \* \* \* \* and secondly, the periodical examination of a water supply, as of a great city, in order that the normal or usual character of the water having been previously ascertained, any suspicious changes which from time to time may occur shall be promptly detected and their cause investigated."

It was proposed only to discuss chemical methods of examination in this paper, and therefore no reference has been made to the microscopical examination of water deposits, or to biological investigations. The former are often of value, and from the latter it was at one time thought, and this is still the opinion of many, that almost everything might be learned, and that chemical analysis had had its day, and was destined to be entirely replaced by biological investigations. Whether the results obtained so far have justified this view is certainly an open question. In my opinion they have not. That such investigations should be made in connection with chemical analyses is generally conceded, and doubtless when our knowledge has increased very valuable results may be obtained thereby, for the probable significance of some classes of micro-organisms seems to be established; but as Mallet has pointed out, basing his statement upon work done by Professor H. Newell Martin, of the Johns-Hopkins University, Dr. George M. Sternberg, U. S. A., and others, there is the difficulty often presented "either by the sparseness, or more frequently the abundance, of those organisms in fairly estimating their average relation to the mass of water," and "this difficulty is superadded, of course, to the imperfection of our knowledge as to the effects upon human health of some closely allied — even hardly distinguishable — organisms of dangerous and harmless associations, and of perhaps the same organism in different stages of its life history."

Two other subjects proposed for discussion remain to be briefly considered. And first as regards the dissemination of diseases by drinking water, there is so much evidence to support the view that polluted waters are prolific sources of disease, that to deny such a cause as an important factor in the propagation of many zymotic diseases, is, to say the least, illogical. Countless sporadic cases of typhoid fever, for

instance, have been traced to the use of drinking water polluted by the dejections of those suffering with this disease, and many epidemics of typhoid and cholera, have been clearly shown to have had a similar origin. I cannot refrain, in this connection, from referring to the history of the cholera epidemics in Glasgow and Manchester during the present century, taking the facts from the Rivers Pollution Commission Report for 1874. Up to 1859 Glasgow drew its water supply from the Clyde, which was polluted by the drainage of towns higher up the river. After that year a pure supply was obtained from Loch Katrine. The deaths from cholera in 1832 were 2,842; in 1849, 3,772; in 1854, 3,886, and in 1866, 16. Manchester and Salford have a similar history. Up to 1851 they took their water partly from the river Irwell and partly from wells, both sources being much polluted. In 1832 there were 890 deaths from cholera: in 1849, 1,115, and after the introduction of pure water in the epidemic of 1854 but 50 cases, and in 1866, 88 cases. It will be observed that in the general epidemic of 1854, Glasgow, using polluted water from the Clyde, had 3,886 deaths from cholera, while Manchester and Salford, with a purer supply, had but 50 deaths. The death rate per thousand per annum of Manchester previous to the introduction of its present water supply, was 33, while in 1880 it was 24.7. (*Usill, Statistics of the Water Supply of the Principal Cities and Towns of Great Britain and Ireland, 1881.*) In 1832 there were 1,000 deaths from cholera in Exeter, England, but after purer water was supplied from a point two miles higher up the river than before, and above the point at which the sewage of the town entered, when cholera again visited the city, in 1849, there were but 44 cases, and in 1854 hardly a single case occurred. In 1854 the water supplied by the Southwark Company in London, was polluted by sewage, while that of the Lambeth Company was much purer. These companies had pipes in the same streets, and supplied consumers indiscriminately on both sides of streets. The deaths from cholera among those who used the Southwark water were 130 in 10,000, while they were but 37 in 10,000 among those using the better water of the Lambeth Company, while in 1849, when that company took water from a point lower down the river than the Southwark, the death rate was largest among those using their water.

Dr. John Simon, Chief Medical Officer of the Privy Council and of the Local Government Board of Great Britain, testified as follows before the Rivers Pollution Commission: "It is, I think, a matter of absolute demonstration that in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was a badness of the water supply then distributed in those districts of London."

In all this nothing has been said about disease germs, for like the chemist's atoms their existence even is not proved, though it seems certain that many diseases are produced by specific poisons, of the nature of which we as yet know little, and that in certain diseases these poisons are contained in the excreta, which may give rise to these same diseases through the use of drinking water to which they have gained access. All filth is not necessarily harmful, a statement which hardly needs proof, but the truth of which is well seen in the case reported by Dr. J. C. McKee, U. S. A., in the *New York Medical Journal* for November 3, 1883, in which water containing large quantities of putrescent animal matter was used for two weeks by a garrison of eighty people, including men, women and children, without producing any deleterious effects, but if some specific kinds of filth *are* poisonous, then the use of a given water which is liable at any time to become specifically polluted, should be abandoned, if possible, in favor of a safer source of supply.

And lastly as regards the natural purification of polluted waters, while the tendency of all organic matter, animal or vegetable, is toward ultimate death and final destruction by oxidation, it is as yet impossible to say how rapidly such a destruction goes on in many cases. The Rivers Pollution Commission mixed urine with water, in the proportion of one part of urine to 3,077 of water, agitated the mixture from time to time and analysed samples. At the end of the eleventh day the improvement in the water was so inconsiderable that other experiments were made in which a stream of impure water was allowed to flow from one vessel to another, and was thus freely exposed to the air, and as a result of these experiments the commissioners concluded that purification by natural oxidation had been greatly overrated, and that "there is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it even at its source." They also conclude that "rivers which have received sewage, even if that sewage has been purified before its discharge are not safe sources of potable water." (Rivers Pollution Commissioners' 6th Report, pp. 134-8.) Upon this point Frankland says: "Twelve years ago there was a general impression amongst chemists and others that polluted water quickly regained its original purity by spontaneous oxidation. The opinion had no foundation in quantitative observations; indeed there was not a single experimented fact to prove it. \* \* \* The impression had gained currency from the improved appearance of a polluted river after a flow of a few miles. \* \* \* Two classes of persons strongly interested in its acceptance were chiefly instrumental in the origination and diffusion of this opinion. These were, first, the polluters of

running water, and secondly water companies drawing their supplies from below the sewer outfalls of towns." (*Journal Chemical Society*, May and July, 1880.) Such improvement as does take place in running streams probably depends more upon the part played by fresh-water plants and micro-organisms than upon direct chemical oxidation, and of course no accurate conclusions can be reached as to the effect of these varying and little understood agencies. Mere dilution also doubtless accounts for the apparent disappearance of much noxious matter. Professor Wm. Ripley Nichols, in his *Water Supply*, italicises the following statement: "*The apparent self-purification of running streams is largely due to dilution, and the fact that a river seems to have purified itself at a certain distance below a point where it was certainly polluted, is no guaranty that the water is fit for domestic use.*"

To what extent, therefore, must a polluted water be diluted before it is safe to use, is a question of the greatest interest, but one to which no answer can as yet be given. Nor can we prove that the specific poisons of certain diseases—admitting their existence—may not contain living organisms capable of rapid multiplication, nor can we tell for how long a period or under what conditions these organisms may retain their vitality. In this absence of positive knowledge, but in the light of countless facts which all but prove our suppositions true, we had best err, if err we must, on the safe side, avoiding the use of polluted waters and recognizing the fact that although chemical analysis may detect no impurities in a water, it is not, therefore, necessarily safe to drink.

The views here presented, may seem extreme to those who have long believed on insufficient grounds that from a chemical analysis alone the character of a drinking water may be decided. My endeavor has been to deal with facts, and make no claims for the chemist's ability in this direction which may not be substantiated, and until we have more knowledge than we now possess of the real causes of disease, and until other methods of analytical research shall have been discovered, it is futile to ask the chemist to recognize and measure forms of matter of which he is ignorant, and to state what will be the effect upon the human system of substances the very nature of which is as yet to him unknown.







